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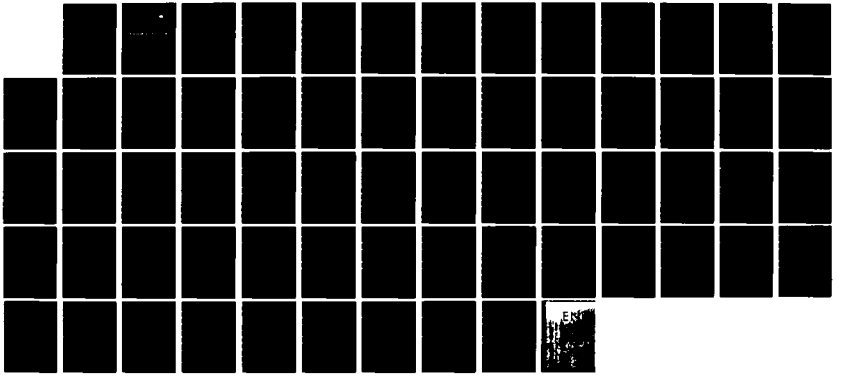

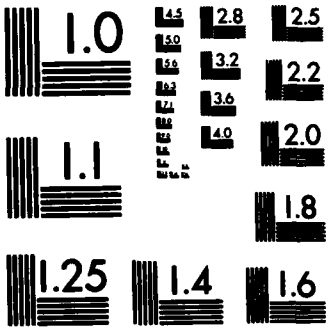

NONPARAMETRIC LEVELS SETTING

OPERATIONS ANALYSIS DEPARTMENT

NAVY FLEET MATERIAL SUPPORT OFFICE
Mechanicsburg, Pennsylvania 17055

Report 156

NONPARAMETRIC LEVELS SETTING
REPORT 156
PROJECT NO. 9322-D86-1301

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Abstract

This study evaluates four distribution free or nonparametric methods for setting levels for "low" and "medium" demand items. The study also analyzes additional techniques for setting the order quantity and the inclusion of economic considerations in setting levels. Performance in the study was measured in terms of an economic statistic resulting from dividing Supply Material Availability (SMA) by the dollar value of the on-hand inventory and the due-in material.

The performance indicates that for "low" demand items, the reorder level should be calculated using the Ordinal Leadtime Method with the order quantity (Q) set equal to one and that purchases be made using the trend purchase criteria. For "medium" demand items, the Ordinal Leadtime Method for calculating the reorder level with Q calculated using the Wilson Economic Order Quantity formula and purchases made using the Trend Purchase Criteria shows an improvement in terms of the performance statistic over the current procedures. However, the SMA that results when these policies are followed is unacceptable; therefore, it is recommended that current procedures for controlling the inventory of "medium" demand items be retained.

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Executive Summary

1. Background. In the Uniform Inventory Control Program (UICP), the decision when to buy is based on the item's reorder level. The reorder level is set equal to the expected leadtime demand plus safety stock. The expected leadtime demand is equal to the quarterly demand forecast multiplied by the leadtime forecast (in quarters). Safety stock is based on the variance of leadtime demand, the acceptable risk of stockout and an assumed probability distribution of leadtime demand. The assumption of a probability distribution is crucial for the accurate setting of the reorder level. Because demand for "low" demand items is erratic, it is unlikely that any standard probability distribution will accurately describe real-world observations. Therefore, Naval Supply Systems Command (NAVSUPSYSCOM) requested Navy Fleet Material Support Office (FMSO) to evaluate four nonparametric methods for setting levels for "low" demand items. The scope of the study was expanded to analyze additional techniques for setting the order quantity, to analyze the inclusion of economic considerations in setting levels and to include "medium" demand items in the analysis.

Using a nonparametric method for setting levels eliminates the need to select a specific probability distribution and requires only one input - a leadtime forecast. Therefore, the procedures for calculating the reorder level become less complex.

2. Objective. To develop a nonparametric approach for controlling the inventory of "low" and "medium" demand items.

3. Approach. Four nonparametric methods were tested for setting the reorder level. These nonparametric methods focus on the order or ranking of the quarterly demands rather than their numerical value. Each of the four nonparametric methods of setting the reorder level were also analyzed when economic considerations were included in setting the reorder level.

In addition to the reorder level, an order quantity (Q) must be determined for each item. Currently, Q is determined based on the Wilson Economic Order Quantity (EOQ) formula. For the "low" demand items, the four nonparametric methods for determining the reorder level were evaluated with Q set equal to one. Four additional techniques for determining Q were analyzed using "low" demand items to determine if any of these methods were more cost effective than setting Q equal to one. For "medium" demand items, the four nonparametric methods for determining the reorder level were evaluated using the current EOQ formula but substituting the average quarterly demand over the most recent four quarters of demand for the quarterly demand forecast usually used in the EOQ calculation.

Two types of purchase criteria were used in this study. The usual criteria is to replenish whenever the asset position was less than or equal to the reorder level. The other purchase criteria used, the Trend Purchase Criteria, ensured that before a purchase was made the demand trend was increasing; i.e., the most recent quarterly demand quantity was at least as great as the quarterly demand quantity which was used to calculate the reorder level.

The Aviation Afloat and Ashore Allowance Analyzer (5A) wholesale inventory simulator was modified to incorporate the Trend Purchase Criteria, and the alternative methods of calculating the reorder level and the order quantity discussed above. The input data consisted of samples of 1H and 1R Cognizance Symbol (Cog) "low" (MARK 0) and "medium" (MARK I and III) demand items. Performance in the study was measured in terms of an economic statistic resulting from dividing Supply Material Availability (SMA) by the dollar value of the on-hand inventory and the due-in material.

4. Findings. None of the four nonparametric methods tested for setting the reorder level, with or without economic considerations, were superior to the others for either the "low" or the "medium" demand items. The Ordinal Leadtime Method is therefore preferred to the others based on simplicity of understanding and implementation. The trend purchase criteria was superior to the current purchase criteria for both "low" and "medium" demand items. None of the four methods for calculating Q, which were tested to see if they improved performance compared to setting Q equal to one for "low" demand items, improved performance.

The Ordinal Leadtime Method for calculating the reorder level with Q set equal to one and purchases made using the trend purchase criteria is preferred to the current procedures of controlling the inventory of "low" demand items. For "medium" demand items, the Ordinal Leadtime Method for calculating the reorder level with Q calculated using the Wilson Economic Order Quantity formula and purchases made using the Trend Purchase Criteria shows an improvement in terms of the performance statistic over the current procedures. However, the SMAs that result when these policies are followed are unacceptable.

5. Recommendation. FMSO recommends that for "low" demand items, the reorder level be calculated using the Ordinal Leadtime Method with Q set equal to one and purchases made using the trend purchase criteria. For "medium" demand items, FMSO recommends that the current procedures for controlling the inventory of "medium" demand items be retained.

I. INTRODUCTION

In the Uniform Inventory Control Program (UICP), the decision when to buy is based on the item's reorder level. If future demand and leadtime are known with certainty the reorder level would equal the demand during leadtime. Since demand and leadtime are random variables, the reorder level is set equal to the expected leadtime demand plus safety stock. The expected leadtime demand is equal to the quarterly demand forecast multiplied by the leadtime forecast (in quarters). Safety stock is based on the variance of leadtime demand, the acceptable risk of stockout and an assumed probability distribution of leadtime demand. The assumption of a probability distribution is crucial for the accurate setting of the reorder level. The demand forecasting and levels setting model (reference (1) of Appendix A) assumes that an item's actual leadtime demand is described by either the Poisson, Negative Binomial or Normal probability distribution. Because demand for "low" demand items is erratic, it is unlikely that any standard probability distribution will accurately describe real-world observations. Reference (2) of Appendix A suggested using a distribution free or nonparametric method as an alternative. Therefore, Naval Supply Systems Command (NAVSUPSYSCOM) requested FMSO in reference (3) of Appendix A, to evaluate four nonparametric methods for setting levels for "low" demand items. Reference (4) of Appendix A expanded the scope of the study to analyze additional techniques for setting the order quantity, to analyze the inclusion of economic considerations in setting levels, and to include "medium" demand items in the analysis.

Using a nonparametric method for setting levels eliminates the need to select a specific probability distribution and requires only one input - a leadtime forecast. Therefore, the procedures for calculating the reorder level

become less complex because there is no longer a need for a quarterly demand forecast, a risk calculation, a shortage cost value, a demand variance and a leadtime variance.

II. TECHNICAL APPROACH

The Technical Approach is divided into the following six sections: Nonparametric Methods, Order Quantity, Purchase Criteria, Simulation Model, Input Data and Output.

A. NONPARAMETRIC METHODS. Four nonparametric methods were tested for setting the reorder level. These nonparametric methods focus on the order or ranking of the quarterly demands rather than their numerical value. For example, three of the four nonparametric methods use the concept of the demand order statistic where given n quarters of demand data, the r^{th} demand order statistic is the quarterly demand such that there are only n-r quarters of demand equal to or greater than it. A description of each method and an example calculation are found below.

The most recent 12 quarters of demand for the example item are distributed as follows (quarter 13 being the current quarter):

Quarter	1	2	3	4	5	6	7	8	9	10	11	12
Demand	0	1	5	2	0	1	3	0	0	1	3	4

The item has a five quarter leadtime, replacement price equal to $100, holding cost rate equal to .23 and an administrative cost per order of $368.

1. Ordinal Leadtime (OL) Method - For an item, given n quarters of demand data, set the reorder level equal to the r^{th} demand order statistic multiplied by the average leadtime.

Using the Ordinal Leadtime Method with n = 8, and r = 7 to calculate the reorder level for the example item results in a reorder level equal to 15. The most recent eight quarters of demand data ordered from low to high are: 0, 0, 0, 1, 1, 3, 3, 4; and the 7^{th} demand order statistic is three which when multiplied by a leadtime of five equals 15.

2. Summed Ordinal Leadtime (SOL) Method - For an item, given n quarters of demand, set the reorder level equal to the r^{th} demand order statistic plus the (r - 1) demand order statistic plus ... plus the (r - (average leadtime - 1)) demand order statistic. Using this method with n = 8 and r = 7 to calculate the reorder level for the example item results in a reorder level equal to 8. The reorder level equals the sum of the 7^{th}, 6^{th}, 5^{th}, 4^{th} and 3^{rd} demand order statistics which are 3, 3, 1, 1, and 0, respectively.

3. Pseudo Leadtime Demand (PLD) Method - For an item, set L equal to the average leadtime rounded to the next highest integer. Calculate n leadtime demand observations as follows: the first leadtime demand observation equals the sum of the L most recent demand quarters. The second leadtime demand observation equals the sum of the L most recent demand quarters when the most recent quarter is excluded ... the n^{th} leadtime demand observation equals the sum of the L most recent demand quarters when the (n - 1) most recent demand quarters are excluded. Set the reorder level equal to the r^{th} order statistic of the n leadtime demand observations calculated above.

Using this method with n = 8, r = 7, and L = 5 to calculate the reorder level for the example item results in a reorder level equal to 9. The eight pseudo leadtime demands (PLD) are listed below:

1^{st} pseudo leadtime demand equals the sum of the 12^{th}, 11^{th}, 10^{th}, 9^{th} and 8^{th} demand quarters which is 4 + 3 + 1 + 0 + 0 = 8.

2^{nd} pseudo leadtime demand equals the sum of the 11^{th}, 10^{th}, 9^{th}, 8^{th} and 7^{th} demand quarters which is 3 + 1 + 0 + 0 + 3 = 7.

3^{rd} pseudo leadtime demand = 1 + 0 + 0 + 3 + 1 = 5.

4^{th} pseudo leadtime demand = 0 + 0 + 3 + 1 + 0 = 4.

5^{th} pseudo leadtime demand = 0 + 3 + 1 + 0 + 2 = 6.

6^{th} pseudo leadtime demand = 3 + 1 + 0 + 2 + 5 = 11.

7^{th} pseudo leadtime demand = 1 + 0 + 2 + 5 + 1 = 9.

8^{th} pseudo leadtime demand = 0 + 2 + 5 + 1 + 0 = 8.

The eight pseudo leadtime demands ordered from low to high are: 4, 5, 6, 7, 8, 8, 9, 11; and the 7^{th} demand order statistic is 9.

4. Percentile (P) Method - For an item, set the reorder level equal to the Y^{th} percentile for n quarters of demand data multiplied by the average leadtime. If the percentile value does not directly correspond to one of the n quarters of demand data, interpolation is used to calculate the reorder level. (For example: if Y = 50 and n = 7, then the reorder level equals the 4^{th} demand order statistic multiplied by the average leadtime; if Y = 50 and n = 6, then interpolation is performed by setting the reorder level equal to the 3^{rd} demand order statistic added to the 4^{th} demand order statistic divided by two and then multiplied by the average leadtime.)

Using the P Method with n = 8 and Y = 50 to calculate the reorder level for the item described above results in a reorder level equal to 5. The 50^{th} percentile, which is interpolated between the 4^{th} and 5^{th} demand order statistics (both equal to 1), is equal to 1 which when multiplied by the leadtime equals 5.

5. Economic Modifications to Nonparametric Methods. Each of the four nonparametric methods of setting the reorder level described above were also analyzed by including economic considerations in setting the reorder level. When economic considerations were included with the OL Method, the SOL Method and the PLD Method, the demand order statistic equals r if the replacement price (Data Element Number (DEN) B055) is less than or equal to the economic dollar breakpoint B, otherwise, the demand order statistic equals r minus the economic adjustment X. When economic considerations were included with the P Method the percentile equals Y if the replacement price is less than or equal to B, otherwise the percentile equals Y-X. For example, calculating the reorder level for the item described above using the SOL Method with economic considerations included and n = 8, r = 7, B = $300 and X = 1 resulted in a reorder level equal to 8 (as seen above in the SOL Method example) since the item's replacement price was less than or equal to $300. However, if the item's replacement price was greater than $300, the demand order statistic (r = 7) would be reduced by X (1) to 6. Under these conditions, the reorder level would equal 5 since the reorder level would then equal the sum of the 6^{th}, 5^{th}, 4^{th}, 3^{rd}, and 2^{nd} demand order statistics which are 3, 1, 1, 0 and 0, respectively.

B. ORDER QUANTITY. In addition to the reorder level, an order quantity (Q) must be determined for each item. Currently, Q is determined based on the Wilson Economic Order Quantity (EOQ) formula as documented in reference (1):

$$EOQ = \sqrt{\frac{8 \times (\text{Cost per order}) \times (\text{Quarterly demand})}{(\text{Holding Cost Rate}) \times (\text{Replacement Price})}}$$

For the "low" demand items, the four nonparametric methods for determining the reorder level were evaluated with Q=1. Using the current purchase criteria

and setting Q equal to one results in a "use one, buy one" policy. Four additional techniques for determining Q were analyzed using "low" demand items to determine if any of these methods were more cost effective than setting Q equal to 1. These five techniques for determining Q and an example of how the Q would be calculated for each technique using data for the hypothetical item described above are found below.

1. Q=1 - set the order quantity equal to one for each item.

2. EOQ (1 yr. ago) - calculate Q using the current EOQ formula but substituting the demand for the quarter one year ago as the quarterly demand forecast usually used in the EOQ calculation. For the item described above, the EOQ (1 yr. ago) method would calculate Q using the current EOQ formula but with the usual quarterly demand forecast set equal to 0 since the demand for the quarter one year previous to the current quarter equals 0. Q would equal 1 since the formula defaults to 1 when demand equals 0.

3. EOQ (Avg 4 Qtr) - calculate Q using the current EOQ formula but substituting the average quarterly demand over the most recent four quarters of demand for the quarterly demand forecast usually used in the EOQ calculation. For the example item, the EOQ (Avg 4 qtr.) method computes Q equal to 16 using the average quarterly demand quantity over the most recent four quarters of demand or $2 = (\frac{0+1+3+4}{4})$.

For the "medium" demand items, the four nonparametric methods for determining the reorder level were evaluated using the EOQ (Avg 4 Qtr) order quantity.

4. Q=Last 4 Qtr - set the order quantity equal to the most recent four quarters of demand. Using this method to calculate Q for the example item results in a Q equal to 8 since the most recent four quarters of demand equals 0, 1, 3, 4. This method equates to an annual buy.

5. Q=2 - set the order quantity equal to two for each item.

C. PURCHASE CRITERIA - Two types of purchase criteria are evaluated. The usual criteria is to replenish whenever the asset position is less than or equal to the reorder level. The other purchase criteria, Trend Purchase Criteria (TPC), requires that the asset position be less than or equal to the reorder level and that the most recent quarter of demand is greater than or equal to the reorder level divided by the average leadtime. The TPC ensures that before a purchase is made the demand trend is increasing; i.e., the most recent quarterly demand is at least as great as the quarterly demand quantity which was used to calculate the reorder level. For example, if a hypothetical item had a reorder level of 9, leadtime of 4, on-hand plus due-in of 8 and the demand for the most recent quarter of 2; then a purchase would be made since the asset position (8) is less than the reorder level (9) and the most recent quarter of demand (2) is at least as large as the reorder level divided by the leadtime (2 = whole number part of (9/4)). However, if the most recent quarter of demand equaled one then a purchase would not have been made.

D. SIMULATION MODEL. The Aviation Afloat and Ashore Allowance Analyzer (5A) wholesale inventory simulator, as described in reference (5) of Appendix A, replicates the inventory management operations for Navy Aviation Supply Office (ASO)-managed material. The 5A wholesale inventory simulator was previously modified to include (1) changes in management policies which have occurred since the initial design and (2) the salient features of the Ships Supply Support Study (S4) Continental United States (CONUS) inventory simulator. The S4 CONUS inventory simulator replicates the inventory management operations for Navy Ships Parts Control Center (SPCC)-managed material, as described in reference (6) of Appendix A.

The simulation model was modified to compute the reorder level using the four nonparametric techniques and the two purchase criteria discussed above. The revised 5A wholesale inventory simulator consisted of a series of time-oriented routines associated with the basic inventory control functions including requisition processing, asset review, and receipt of material from purchase. All processing involved in these routines is accomplished on an item by item basis. Impetus to the simulator is provided in the form of demands placed against the system.

Requisitions are considered satisfied only if enough material is available to satisfy the entire demand. Periodically, the asset position of each item is reviewed to determine if a purchase action is required using one of the two types of purchase criteria discussed above.

In cases where a purchase action is required, a receipt of material from purchase is scheduled to occur after a leadtime. Leadtimes are determined using a normally distributed pseudo random number and the item's mean and standard deviation of leadtime. Reorder levels are recomputed on a quarterly basis. During the processing outlined above various cost and performance statistics are displayed every year.

E. INPUT DATA. Low demand (MARK 0 - Average Quarterly Demand $\leq$ .25) and medium demand (MARK I and III - .25 < Average Quarterly Demand $\leq$ 5.0) items from two segments of Navy-managed inventory (1H and 1R cog items) were used in this study. The March 1981 Selective Item Generator (SIG) file was the primary source of basic item information; e.g., unit price, average leadtime. The SIG provides a snapshot of the UICP Master Data File (MDF).

Actual demand transactions were used as the demands in the simulation for this analysis. Transaction Item Reporting (TIR) historical files contain the actual demand transactions. For SPCC-managed material (1H Cognizance Symbol

(Cog)) seven years (January 1974 - December 1980) of TIR data were available, while five years of TIR data (October 1975 - December 1980) were used for ASO-managed material (1R Cog). Only items which were in the March 1981 SIG and had at least one demand in the indicated demand periods were included in the input data.

The input data was grouped by Cog. Because the number of items per Cog was so large and would consume too much computer time if simulated without sampling, systematic random samples were selected from each Cog. Since the output data from a simulation run are random variables which may have large variances, they could, in a particular simulation run differ greatly from the corresponding "true" values. The net effect is that there may be a significant probability of making erroneous inferences about the system under study if only one simulation run is made. Therefore, multiple samples were selected within each cog to achieve more confidence and precision in evaluating the nonparametric techniques. The manner in which the input was categorized is illustrated in TABLE I. An analysis of each sample and the universe indicated that each sample was distributed the same as the universe in terms of Standard Price (DEN B053) and Quarterly System Demand Forecast (DEN B074) which indicates that the samples were representative of the universe.

TABLE I
Input Categorization

	Cog	# Samples	# Items Sample I	# Items Sample II	# Items Sample III	# Items Sample IV
Low Demand	1H	4	1,542	1,542	1,542	1,542
	1R	4	1,504	1,503	1,503	1,503
Med. Demand	1H	4	1,509	1,509	1,508	1,508
	1R	4	1,564	1,564	1,564	1,564

F. OUTPUT. The first two years of simulation were treated as a transition period and not included in the statistical measures. The statistics defined below were considered the most relevant for evaluating the four nonparametric techniques and the purchase criteria analyzed in this study.

1. $OH+$DI - Dollar Value of Material On-Hand plus Dollar Value of Procurements Due-In - Dollar value of inventory investment at the end of the simulated year.

2. SMA - Supply Material Availability - The sum of the requisitions satisfied immediately divided by the total number of requisitions submitted. A requisition is considered satisfied only if the entire requisition is satisfied.

3. ADD - Average Days Delay - The time delay experienced by all backordered requisitions divided by the total number of requisitions submitted.

4. #PI - Number of Procurements Initiated - Average number of procurement orders placed during a year. #PI is a measure of the workload at the Inventory Control Points (ICPs).

5. SMA/($OH+$DI) - Supply Material Availability divided by the Dollar Value of Material On-Hand plus Dollar Value of Procurements Due-In - SMA was divided by $OH+$DI per $100,000 resulting in an economic consideration. The SMA/($OH+$DI) ratio is a measure of how much SMA is purchased per dollar of investment (on the average). The higher the value of the ratio the more effectively the investment is being spent.

III. FINDINGS

The Findings are divided into the following three sections: "Low" Demand Items, "Medium" Demand Items and Current Procedures versus Ordinal Leadtime Method.

A. "LOW" DEMAND ITEMS. The "Low" Demand Items section of the Findings has four divisions which are: Purchase Criteria, Nonparametric Methods for Calculating Reorder Level, Economic Considerations and Order Quantity.

1. Purchase Criteria (Current Purchase Criteria vs. Trend Purchase Criteria) - Two types of purchase criteria were used as discussed in the approach. TABLEs II and III display the SMA/($OH+$DI) statistic for each 1H and 1R Cog replication when the current purchase criteria and the trend purchase criteria were used. Q was set equal to one for each item. TABLEs II and III also display the difference between the SMA/($OH+$DI) statistic when using the current purchase criteria and trend purchase criteria. TABLE II displays the SMA/($OH+$DI) statistic for each nonparametric method of calculating the reorder level when the demand order statistic, the quarters of demand data and the percentile were set equal to 6, 8, and 75, respectively, while TABLE III displays the SMA/($OH+$DI) statistic for each method when the demand order statistic, the quarters of demand data and the percentile were set equal to 1, 8, and 15, respectively. The order statistic and the percentile were varied (6 vs. 1 and 75 vs. 15, respectively) to decrease the chance that they may bias the results of testing the current purchase criteria versus the trend purchase criteria. That is, the relationship between the current purchase criteria and the trend purchase criteria could be different dependent on the value of the order statistic or percentile. By using both a high and low value for the order statistic and the percentile, the chance of misreading the relationship between these two purchase criteria was decreased.

TABLE II
Current Purchase Criteria vs. Trend Purchase Criteria
Demand Order Statistic and Percentile Equal High Value
SMA/($OH+$DI) for Low Demand Items

	1H				1R			
	Replication 1	Replication 2	Replication 3	Replication 4	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method								
6th Demand Order Statistic								
Trend Purchase Criteria	4.2465	3.855	3.1281	2.8187	4.6021	2.6734	4.9489	4.7941
Current Purchase Criteria	3.4128	.5763	2.3419	2.2832	3.3478	2.0947	3.7287	3.3214
Difference	.8337	3.2787	.7862	.5355	1.2543	.5787	1.2202	1.4727
Summed Ordinal Leadtime Method								
6th Demand Order Statistic								
Trend Purchase Criteria	4.6491	4.1599	3.8801	3.0914	4.8522	2.9541	4.9821	4.7069
Current Purchase Criteria	3.982	1.0341	2.6397	2.41	4.5544	2.7571	4.782	4.5184
Difference	.6671	3.1258	1.2404	.6814	.2978	.197	.2001	.1885
Pseudo Leadtime Demand Method								
6th Demand Order Statistic								
Trend Purchase Criteria	3.7623	1.1872	3.0019	2.0134	3.8729	2.7549	3.9108	3.6767
Current Purchase Criteria	3.0844	.3928	2.1261	.7171	3.3533	1.8083	3.6084	3.4433
Difference	.6779	.7944	.8758	1.2963	.5196	.9466	.3024	.2334
Percentile Method								
75th Percentile								
Trend Purchase Criteria	3.44	.6061	2.7602	2.4823	3.7976	2.1144	3.2518	3.4241
Current Purchase Criteria	2.6512	.2773	1.6252	1.4433	2.6011	1.6172	2.8632	2.7251
Difference	.7888	.3288	1.135	1.039	1.1965	.4972	.3886	.699

NOTE: Quarters of Demand Data = 8

TABLE III
Current Purchase Criteria vs. Trend Purchase Criteria
Demand Order Statistic and Percentile Equal Low Value
SMA/($OH+$DI) for Low Demand Items

	IR				IR			
	Replication 1	Replication 2	Replication 3	Replication 4	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method								
1st Demand Order Statistic								
Trend Purchase Criteria	4.55	3.9196	4.1269	2.9999	5.0547	2.6029	5.411	4.7182
Current Purchase Criteria	3.95	3.0915	2.6925	2.4012	5.0	2.5634	5.2274	4.6727
Difference	.6	.8281	1.4344	.5987	.0547	.0395	.1836	.0455
Summed Ordinal Leadtime Method								
1st Demand Order Statistic								
Trend Purchase Criteria	4.52	3.9437	4.1621	2.9844	5.1654	2.6029	5.1516	4.8634
Current Purchase Criteria	3.79	3.0426	2.6373	2.2832	5.0	2.5599	5.2234	4.6723
Difference	.73	.9011	1.5248	.7012	.1654	.043	-0.0718	.1911
Pseudo Leadtime Demand Method								
1st Demand Order Statistic								
Trend Purchase Criteria	4.36	1.0552	3.256	2.9632	4.6378	3.3114	4.2592	4.2917
Current Purchase Criteria	3.68	1.022	2.2873	2.0134	3.9967	2.1501	4.2139	4.1652
Difference	.68	.0332	.9687	.9498	.6411	1.1613	.0453	.1265
Percentile Method								
15th Percentile								
Trend Purchase Criteria	4.66	3.9883	4.2407	3.0556	5.0621	2.6032	5.3319	4.9872
Current Purchase Criteria	4.46	3.8842	3.7711	2.9513	5.0621	2.5848	5.308	4.9391
Difference	.2	.1041	.4696	.1043	0.0	.0184	.0234	.0481

NOTE: Quarters of Demand Data = 8

There was only one instance where using the current purchase criteria increased the SMA/($OH+$DI) statistic when compared to using the trend purchase criteria (TABLE III, SOL Method, 1R Cog, Replication 3). Therefore, it was hypothesized that the trend purchase criteria is superior to the current purchase criteria. To test this hypothesis the differences displayed in TABLEs II and III were used to construct a paired-t confidence interval, as discussed in Section 9.2 of reference (7). TABLE IV displays the 90 percent confidence intervals for the difference between the SMA/($OH+$D1) statistic when the current purchase criteria is used versus using the trend purchase criteria. (Appendix B contains an example of how the differences found in TABLEs II and III were used to develop the paired-t confidence intervals found in TABLE IV.) The hypothesis is rejected if the interval contains zero. For 11 of 16 cases with 90 percent confidence, we can conclude that the trend purchase criteria is superior to the current purchase criteria when performance is measured by the SMA/($OH+$DI) statistic. For the five cases where the interval contained zero we conclude that the trend purchase criteria is as good as the current purchase criteria. Therefore, based on the analysis of the paired-t confidence intervals shown in TABLE IV we conclude that the trend purchase criteria is preferred to the current purchase criteria for "low" demand items.

TABLE IV
Paired-t 90% Confidence Intervals for the SMA/($OH+$DI) Statistic
Trend Purchase Criteria Minus Current Purchase Criteria

	1H	1R
Ordinal Leadtime Method Demand Order Statistic = 6	(-.1553, 2.8724)	(.6783, 1.5845)
Summed Ordinal Leadtime Method Demand Order Statistic = 6	(.0610, 2.7963)	(.1602, .2814)
Pseudo Leadtime Demand Method Demand Order Statistic = 6	(.5941, 1.2279)	(.1223, .8786)
Percentile Method Percentile = 75	(.3990, 1.246)	(.2741, 1.1165)
Ordinal Leadtime Method Demand Order Statistic = 1	(.4012, 1.3293)	(-.0001, .1617)
Summed Ordinal Leadtime Method Demand Order Statistic = 1	(.5125, 1.4160)	(-.0606, .2244)
Pseudo Leadtime Demand Method Demand Order Statistic = 1	(.1439), 1.1718)	(-.1152, 1.1023)
Percentile Method Percentile = 15	(.0162, .4227)	(-.0007, .0459)

NOTE: Quarters of Demand Data = 8

2. Nonparametric Methods for Calculating Reorder Level - Four nonparametric methods were tested for calculating the reorder level for "low" demand items as discussed in the approach. Q was set equal to one and the trend purchase criteria was used as the purchase criteria for all items. TABLE V displays the average and 90 percent confidence intervals for the SMA/($OH+$DI) statistic using the four replications for the 1H and 1R items as the demand order statistic or the percentile was varied for the four methods. Appendix C contains the SMA/($OH+$DI) statistic for the four 1H and 1R replications which were used to calculate these averages and confidence intervals. (Appendix C also contains the SMA, $OH+$DI, ADD and #PI statistics for the four 1H and the four 1R replications as the demand order statistic or the percentile was varied for the four methods.)

To test whether one of the nonparametric methods for setting the reorder level for "low" demand items is more cost effective than the others, the best setting for the demand order statistic or the percentile was chosen for each method. Thus, the order statistic or percentile which produced the largest average SMA/($OH+$DI) statistic was defined as the best setting. TABLE VI displays the best order statistic or percentile for each method, the value of the SMA/($OH+$DI) statistic for each replication and the resulting average SMA/($OH+$DI) statistic. It is hypothesized that within each Cog the average SMA/($OH+$DI) statistics are equal for each method. A one factor analysis of variance (ANOVA) was performed for each cog to test these hypotheses and are displayed in TABLE VII. The critical value of F for .05 significance with 3 and 12 degrees of freedom is 3.49, which is larger than the F-test statistics of 1.42 for 1H items and .303 for 1R items. Therefore, there is not sufficient evidence to reject the hypothesis for either Cog.

TABLE V

Average and 90% Confidence Intervals for the SMA/($OH+$DI) Statistic

	1H	1R
Ordinal Leadtime Method,		
Demand Order Statistic = 7	2.4393 ± 1.6009	4.0499 ± 1.0637
6	3.5120 ± .7700	4.2546 ± 1.2513
5	3.8690 ± .7438	4.6383 ± .8589
4	3.9123 ± .8091	4.5421 ± 1.5710
3	3.8901 ± .7896	4.4409 ± 1.4737
2	3.9244 ± .7574	4.4342 ± 1.4625
1	3.8991 ± .7698	4.4467 ± 1.4839
Summed Ordinal Leadtime Method,		
Demand Order Statistic = 7	2.9301 ± 1.5398	4.0367 ± 1.1061
6	3.9545 ± .7669	4.3738 ± 1.1213
5	4.0428 ± .8481	4.6138 ± .8301
4	3.9867 ± .7927	4.3806 ± 1.4402
3	3.9073 ± .7760	4.3564 ± 1.3623
2	3.9386 ± .8072	4.4357 ± 1.4376
1	3.9025 ± .7724	4.4458 ± 1.4547
Pseudo Leadtime Demand Method,		
Demand Order Statistic = 7	2.5898 ± 1.2142	3.5447 ± .7330
6	2.6234 ± 1.2725	3.5538 ± .6381
5	2.6817 ± 1.3640	3.5735 ± .7393
4	2.7921 ± 1.4221	3.7443 ± .8866
3	2.8305 ± 1.4777	3.7504 ± .9335
2	2.8803 ± 1.5490	3.8853 ± 1.0054
1	2.9086 ± 1.6167	4.1250 ± .6692
Percentile Method,		
Percentile = 85	1.8437 ± 1.0404	2.6999 ± .5486
75	2.3220 ± 1.4267	3.1469 ± .8530
65	2.6708 ± 1.5507	3.8366 ± .7871
50	3.914 ± .7851	4.3645 ± 1.1214
35	3.9878 ± .8043	4.4878 ± 1.0932
25	3.9533 ± .7417	4.3828 ± 1.3782
15	3.9861 ± .7993	4.4961 ± 1.4948

NOTE: Quarters of Demand Data = 8

TABLE VI
The "Best" Demand Order Statistic or Percentile for Each Nonparametric Method

1H

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 2	4.5274	3.9738	4.1748	3.0217	3.9244
Summed Ordinal Leadtime Method - Dmd Order Statistic = 5	4.7708	4.2525	4.0963	3.0516	4.0428
Pseudo Leadtime Dmd Method - Dmd Order Statistic = 1	4.36	1.0552	3.256	2.9632	2.9086
Percentile Method - Percentile = 35	4.702	4.1469	4.0438	3.0585	3.9878

1R

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 5	5.0173	3.5433	4.9957	4.9971	4.6383
Summed Ordinal Leadtime Method - Dmd Order Statistic = 5	4.8422	3.5655	5.08	4.9676	4.6138
Pseudo Leadtime Dmd Method - Dmd Order Statistic = 1	4.6378	3.3114	4.2592	4.2917	4.1250
Percentile Method - Percentile = 15	5.0621	2.6032	5.3319	4.9872	4.4961

TABLE VII
ANOVA Table

1H

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-Ratio
Between Methods	3.5040	3	1.1680	1.42
Residual	9.8703	12	0.8225	
Total	13.3744	15		

1R

Between Methods	.6748	3	0.2249	0.303
Residual	8.9066	12	0.7422	
Total	9.5814	15		

Since there is not sufficient evidence to choose one of the methods based on how effectively the method spends money, the OL Method is the preferred nonparametric method because of simplicity of understanding and implementation.

3. Economic Considerations. As discussed in the Technical Approach, each nonparametric method for setting the reorder level was also analyzed when economic considerations were included in setting the reorder level. TABLE VIII displays the SMA/($OH+$DI) statistic for each 1H and 1R Cog replication when the four nonparametric methods for setting the reorder level used the best setting for the demand order statistic or the percentile with and without the economic considerations. When the economic considerations were used, the economic dollar breakpoint (B) equaled $300.00 and the economic adjustment (X) equaled one. TABLE VIII also displays the difference between the SMA/($OH+$DI) statistic when the economic considerations were included and when they were excluded. It is hypothesized that the SMA/($OH+$DI) statistic is the same with or without the economic considerations. To test this hypothesis the differences displayed in TABLE VIII were used to construct paired-t confidence intervals as discussed previously. TABLE IX displays the 90 percent confidence intervals for the difference between the SMA/($OH+$DI) statistic when the economic considerations are used versus not using them. The hypothesis is rejected if the interval does not contain zero. For 1H items, when the OL Method is used to calculate the reorder level, with 90 percent confidence, we can conclude that it is better not to include the economic considerations, while when the SOL Method or the PLD Method is used we can conclude that it is better to include the economic considerations. For 1H items used with the P Method and for 1R items used with any of the four nonparametric methods, we cannot conclude that there is any difference whether or not the economic consideration is used in calculating the reorder level. So, in summary, we can conclude that including economic considerations improves the SMA/($OH+$DI) statistic only for 1H items when the SOL and PL Methods are used to calculate the reorder level.

TABLE VIII
SMA/$OH+$DI Statistics When Economic Considerations were Included

1H

	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method Demand Order Statistic = 2				
W/O Economic Consideration	4.5274	3.9738	4.1748	3.0217
W/Economic Consideration	4.3571	3.6995	3.9587	2.9892
Difference	.1703	.2743	.2161	.0325
Summed Ordinal Leadtime Method Demand Order Statistic = 5				
W/O Economic Consideration	4.7708	4.2525	4.0963	3.0516
W/Economic Consideration	4.7857	4.2965	4.2742	3.2032
Difference	-.0149	-.044	-.1779	-.1516
Pseudo Leadtime Demand Method Demand Order Statistic = 1				
W/O Economic Consideration	4.36	1.0552	3.256	2.9632
W/Economic Consideration	4.6308	1.0343	3.4563	3.1104
Difference	-.2708	.0209	-.2003	-.1472
Percentile Method Percentile = 35				
W/O Economic Consideration	4.702	4.1469	4.0438	3.0585
W/Economic Consideration	4.8292	4.1195	4.1783	3.1507
Difference	-.1272	.0274	-.1345	-.0922

NOTE: Quarters of Demand Data = 8

TABLE VIII (Cont'd)
SMA/$OH+$DI Statistics When Economic Considerations were Included

1R

	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method Demand Order Statistic = 5				
W/O Economic Consideration	5.0173	3.5433	4.9957	4.9971
W/Economic Consideration	4.902	2.66	5.338	5.1693
Difference	.1153	.8833	-.3423	-.1722
Summed Ordinal Leadtime Method Demand Order Statistic = 5				
W/O Economic Consideration	4.8422	3.5655	5.08	4.9676
W/Economic Consideration	4.9662	2.934	5.3083	4.953
Difference	-.124	.6315	-.2283	.0146
Pseudo Leadtime Demand Method Demand Order Statistic = 1				
W/O Economic Consideration	4.6378	3.3114	4.2592	4.2917
W/Economic Consideration	4.502	2.8469	4.454	4.6666
Difference	.1358	.4645	-.1948	-.3749
Percentile Method Percentile = 15				
W/O Economic Consideration	5.0621	2.6032	5.3319	4.9872
W/Economic Consideration	5.0621	2.6029	5.3319	4.9872
Difference	0	.0003	0	0

NOTE: Quarters of Demand Data = 8

TABLE IX
Paired-t 90% Confidence Intervals for the SMA/($OH+$DI) Statistic
Without Economic Considerations minus With Economic Considerations

	1H	1R
Ordinal Leadtime Method	(.0520, .2945)	(-.5168, .7588)
Summed Ordinal Leadtime Method	(-.1909, -.0032)	(-.3796, .5265)
Pseudo Leadtime Demand Method	(-.2955, -.0031)	(-.4285, .4438)
Percentile Method	(-.1698, .0066)	(-.0001, .0002)

In the Nonparametric Methods for Calculating Reorder Level for "Low" Demand Items section of the findings, we hypothesized that within Cog the average SMA/($OH+$DI) statistics are equal for each method and tested this hypothesis using a one factor ANOVA test. Since for 1H items including the economic considerations increases the SMA/($OH+$DI) statistic for the SOL and PLD Methods, we next test the hypothesis that for 1H items the average SMA/($OH+$DI) statistics are equal for the OL and P Methods without economic considerations and the SOL and PLD Methods with the economic considerations. TABLE X displays the value of the SMA/($OH+$DI) statistic for each replication and the average SMA/($OH+$DI) statistic for each method. A one factor ANOVA was performed to test the hypothesis and is displayed in TABLE XI. The critical value of F for .05 significance with 3 and 12 degrees of freedom is 3.49, which is larger than the F-test statistic of 1.068. Therefore, there is not sufficient evidence to reject the hypothesis.

TABLE X
Average SMA/($OH+$DI) Statistic for 1H Material

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method Demand Order Statistic = 2 W/O Economic Considerations	4.5274	3.9738	4.1748	3.0217	3.9244
Summed Ordinal Leadtime Method - Demand Order Statistic = 5 W/Economic Considerations	4.7857	4.2965	4.2742	3.2032	4.1399
Pseudo Leadtime Demand Method - Demand Order Statistic = 1 W/Economic Considerations	4.6308	1.0343	3.4563	3.1104	3.0579
Percentile Method Percentile = 35 W/O Economic Considerations	4.702	4.1469	4.0438	3.0585	3.9878

NOTE: Quarters of Demand Data = 8

TABLE XI
ANOVA Table

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-Ratio
Between Methods	2.8596	3	0.9532	1.068
Residual	10.7132	12	0.8928	
Total	13.5728	15		

Since including economic considerations with the SOL Method or the PLD Method did not improve their SMA/($OH+$DI) statistics enough to prefer one of these methods over the others, the OL Method without economic considerations remains the preferred nonparametric method because of simplicity of understanding and implementation.

4. Order Quantity - As discussed in the approach, four methods of calculating Q for low demand items were tested besides setting Q equal to one. These four methods of calculating Q were tested to indicate whether money would be spent more efficiently for low demand items than when Q is set equal to one. TABLEs XII and XIII display the average SMA/($OH+$DI) statistic along with each replication's SMA/($OH+$DI) for each method of calculating Q. The tables are subdivided by purchase criteria and method of calculating the reorder level for 1H and 1R Cog, respectively. (For the reorder level calculation, the demand order statistic was set to seven and percentile equaled 85.) Visual inspection of TABLEs XII and XIII indicates that for low demand items when any of the four alternative methods are used to calculate Q, money is not spent any more efficiently than when Q is set equal to one.

TABLE XII

SMA/(SOH+SDI) Statistics for Alternative Methods of Calculating Q for IH Material

	Current Purchase Criteria					Trend Purchase Criteria				
	Q=1	EOQ (1 yr ago)	EOQ (Avg 4 Qtr)	Q=Last 4 Qtr	Q=2	Q=1	EOQ (1 yr.ago)	EOQ (Avg 4 Qtr)	Q=Last 4 Qtr	Q=2
Ordinal Leadtime Method										
Replication 1	2.4088	1610	.1694	.1951	.1604	3.7805	.1413	.1549	.1398	.1416
Replication 2	.2296	2379	.2206	.1566	.2410	.5434	.5260	.5755	.4056	.6059
Replication 3	1.5719	1.3761	1.4607	1.2184	1.4978	2.7807	2.2769	2.6541	2.4380	2.5397
Replication 4	1.3975	7227	.6707	.4443	.7823	2.6526	2.3345	.9563	.8065	.9478
Average	1.402	6242	.6394	.4946	.6704	2.4393	1.3197	1.0852	.9475	1.0588
Summed Ordinal Leadtime Method										
Replication 1	3.5904	1534	.1633	.1520	.1511	4.2785	.1488	.1601	.1470	.1461
Replication 2	.3616	.3871	.3399	2.072	.3919	1.1439	.9242	1.0102	.6152	1.1301
Replication 3	2.3566	1.8489	2.0524	1.5252	2.0529	3.2813	2.3126	2.7952	2.3833	2.6246
Replication 4	2.0275	8245	.7652	.7484	.8862	3.0166	.9368	1.0022	.8296	1.0009
Average	2.084	8034	.8034	.6582	.8705	2.9301	1.0806	1.2419	.9938	1.2252
Pseudo Leadtime Demand Method										
Replication 1	3.0149	1644	.1689	.1660	.1633	3.6679	.1537	1.5976	.1554	.1541
Replication 2	.4009	3418	.3510	.2206	.4115	1.2126	.9322	.9966	.1642	1.1577
Replication 3	2.1440	1.6663	1.8487	1.4547	1.8999	2.9542	2.3318	2.5621	2.3213	2.4748
Replication 4	.7218	5246	.4817	.3528	.5323	2.5247	.9458	.9729	.8963	.9688
Average	1.5704	6744	.7140	.922	.7518	2.5898	1.0909	1.5322	1.0039	1.1888
Percentile Method										
Replication 1	1.8582	1726	.1742	.1726	.1725	2.5952	.1472	.1495	.1505	.1518
Replication 2	.2527	2478	.2252	.1708	.2545	.5844	.5263	5380	.4252	.6045
Replication 3	1.3201	1.1654	1.1859	1.0389	1.2360	2.2806	2.1175	2.1377	2.1035	2.0901
Replication 4	.4575	9622	.3487	2815	.3746	1.9145	.8564	.8586	.8273	.8880
Average	9721	487	.4835	.416	.5094	1.8437	.9119	.9207	.8766	.9336

NOTE: Quarters of Demand = 8

TABLE XIII

SMA/($OH+$DI) Statistics for Alternative Methods of Calculating Q for IR Material

	Current Purchase Criteria					Trend Purchase Criteria				
	Q=1	EOQ (1 yr.ago)	EOQ (Avg 4 Qtr)	Q=Last 4 Qtr	Q=2	Q=1	EOQ (1 yr.ago)	EOQ (Avg 4 Qtr)	Q=Last 4 Qtr	Q=2
Ordinal Leadtime Method										
Replication 1	2.5701	2.1519	2.2078	2.1062	2.2641	4.7921	3.2859	3.6818	3.7314	3.5559
Replication 2	1.6633	.5965	.5761	.5256	.6196	2.7130	.5726	.6042	.5275	.6025
Replication 3	2.8041	2.1810	2.2973	2.2192	2.2309	4.5727	2.8822	3.2434	3.1978	3.0098
Replication 4	2.6985	2.3073	2.3858	2.2504	2.4713	4.6307	3.5563	4.0106	3.9426	3.747
Average	2.434	1.8092	1.8668	1.7529	1.8965	4.1771	2.5742	2.885	2.8498	2.7288
Summed Ordinal Leadtime Method										
Replication 1	3.9622	3.0046	3.2862	2.7957	3.1868	4.9778	3.4464	3.6384	3.4538	3.5438
Replication 2	2.0522	.5753	.6211	.5569	.6492	2.6354	.6112	.6359	.5500	.6442
Replication 3	4.2105	2.8757	3.1024	2.9411	2.9801	4.4746	2.8983	3.1857	3.1091	3.0185
Replication 4	4.1093	3.2451	3.4663	3.0905	3.4901	4.6454	3.3955	3.7198	3.4156	3.6985
Average	3.5835	2.4251	2.619	2.3461	2.5766	4.1833	2.5879	2.7949	2.6321	2.7262
Pseudo Leadtime Demand Method										
Replication 1	3.3721	2.6794	2.8150	2.5343	2.8967	4.0155	3.2480	3.2404	3.1873	3.2113
Replication 2	1.5787	.5331	.5840	.5208	.6199	2.6262	.6477	.6757	.5851	.6730
Replication 3	3.6866	2.5659	2.7702	2.5538	2.7411	3.7718	2.8127	2.8551	2.7755	2.8304
Replication 4	3.3284	2.7157	2.7987	2.6626	3.0432	4.0136	3.2773	3.4865	3.3394	3.4353
Average	2.9915	2.1235	2.242	2.0679	2.3252	3.6068	2.4964	2.5624	2.4718	2.5375
Percentile Method										
Replication 1	1.9624	1.8744	1.7212	1.6569	1.7962	3.1732	2.9546	2.6298	2.6799	2.5058
Replication 2	.8508	.4708	.4540	.4307	.4731	2.0266	.6276	.638	.6099	.6307
Replication 3	2.0598	1.896	1.7065	1.7271	1.7838	2.7457	2.4673	2.3731	2.4061	2.2423
Replication 4	1.9305	1.8800	1.6791	1.7170	1.8093	3.0251	2.9430	2.7923	2.8293	2.7373
Average	1.7009	1.2803	1.3902	1.3829	1.4656	2.7427	2.2481	2.1083	2.1313	2.029

NOTE: Quarters of Demand = 8

B. "MEDIUM" DEMAND ITEMS. The "Medium" Demand Items section of the Findings is divided into a Purchase Criteria division and a Nonparametric Method for Calculating Reorder Level division.

1. Purchase Criteria (Current Purchase Criteria vs. Trend Purchase Criteria) - The current purchase criteria and the trend purchase criteria were also analyzed with the "medium" demand items. TABLEs XIV and XV display the SMA/($OH+$DI) statistic for each 1H and 1R Cog replication when the current purchase criteria and the trend purchase criteria were used as the purchase criteria. TABLEs XIV and XV also display the difference between the SMA/($OH+$DI) statistic when using the current purchase criteria and the trend purchase criteria. TABLE XIV displays the SMA/($OH+$DI) statistic for each nonparametric method of calculating the reorder level when the demand order statistic, the quarters of demand data and the percentile were set equal to 6, 8 and 75, respectively, while TABLE XV displays the SMA/($OH+$DI) statistic for each method when the demand order statistic, the quarters of demand data and the percentile were set equal to 1, 8, and 15, respectively.

Out of 64 comparisons, there were only 12 instances where using the current purchase criteria increased the SMA/($OH+$DI) statistic when compared to using the trend purchase criteria. Therefore, it is hypothesized that the trend purchase criteria is superior to the current purchase criteria. To test this hypothesis the differences displayed in TABLEs XIV and XV were used to construct a paired-t confidence interval. TABLE XVI displays the 90 percent confidence intervals for the difference between the SMA/($OH+$DI) statistic for the two purchase criteria. The hypothesis is rejected if the interval contains zero.

TABLE XIV

Current Purchase Criteria vs. Trend Purchase Criteria
Demand Order Statistic and Percentile Equal High Value
SMA/($OH+$DI) for Medium Demand Items

	IH				IR			
	Replication 1	Replication 2	Replication 3	Replication 4	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method								
6th Demand Order Statistic								
Trend Purchase Criteria	1.2769	.8907	.0672	1.4468	1.3031	1.7722	1.4336	1.3805
Current Purchase Criteria	1.1583	.893	.0249	1.1493	1.1329	1.4696	1.1349	1.0582
Difference	.1186	-.0023	.0423	.2975	.1702	.3026	.2987	.3223
Summed Ordinal Leadtime Method								
6th Demand Order Statistic								
Trend Purchase Criteria	1.4136	.9291	.0636	1.51	1.3848	1.9922	1.5382	1.449
Current Purchase Criteria	1.29	.9051	.0335	1.3351	1.3939	1.8987	1.4495	1.344
Difference	.1236	.024	.0301	.1749	-.0091	.0935	.0887	.105
Pseudo Leadtime Demand Method								
6th Demand Order Statistic								
Trend Purchase Criteria	1.3026	.9556	.0725	1.4464	1.331	1.786	1.4071	1.3248
Current Purchase Criteria	1.015	.8428	.0396	1.1928	.9487	1.619	1.3052	1.1708
Difference	.2876	.1128	.0329	.2536	.3823	.167	.1019	.154
Percentile Method								
75th Percentile								
Trend Purchase Criteria	1.1705	.9118	.0741	1.3486	1.0868	1.4835	1.3071	1.265
Current Purchase Criteria	1.0372	.8155	.0279	1.0169	.9383	1.2548	.9876	1.0075
Difference	.1333	.0963	.0462	.3317	.1485	.2287	.3195	.2575

NOTE: Quarters of Demand Data = 8

TABLE XV

Current Purchase Criteria vs. Trend Purchase Criteria
Demand Order Statistic and Percentile Equal Low Value
SMA/($OH+$DI) for Medium Demand Items

	1H				1R			
	Replication 1	Replication 2	Replication 3	Replication 4	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method								
1st Demand Order Statistic								
Trend Purchase Criteria	1.3157	.7275	.0454	1.3506	1.4513	2.1764	1.4626	1.557
Current Purchase Criteria	1.2156	.7247	.047	1.2826	1.4498	2.0784	1.5109	1.4603
Difference	.1001	.0028	-.0016	.068	.0015	.098	-.0483	.0967
Summed Ordinal Leadtime Method								
1st Demand Order Statistic								
Trend Purchase Criteria	1.3285	.7514	.0457	1.3631	1.4513	2.1761	1.4626	1.557
Current Purchase Criteria	1.2026	.7190	.0469	1.2778	1.4206	2.0431	1.5208	1.4469
Difference	.1259	.0324	-.0012	.0853	.0307	.133	-.0582	.1101
Pseudo Leadtime Demand Method								
1st Demand Order Statistic								
Trend Purchase Criteria	1.3686	.9034	.0596	1.5302	1.331	1.786	1.4967	1.433
Current Purchase Criteria	1.2495	.8427	.0306	1.2595	1.1222	1.7902	1.4257	1.3233
Difference	.1191	.0607	.029	.2707	.2088	-.0042	.071	.1097
Percentile Method								
15th Percentile								
Trend Purchase Criteria	1.3273	.7842	.0465	1.3192	1.0869	2.0963	1.5525	1.441
Current Purchase Criteria	1.3502	.7769	.0472	1.3232	1.4447	2.0548	1.5112	1.4736
Difference	-.0229	.0073	-.0007	-.004	-.3578	.0415	.0413	-.0326

NOTE: Quarters of Demand Data = 8

TABLE XVI
Paired-t 90% Confidence Intervals for the SMA/($OH+$DI) Statistic
Trend Purchase Criteria Minus Current Purchase Criteria

	1H	1R
Ordinal Leadtime Method Demand Order Statistic = 6	(-.0414, .2694)	(.1915, .3553)
Summed Ordinal Leadtime Method Demand Order Statistic = 6	(.0015, .1747)	(.0073, .1317)
Pseudo Leadtime Demand Method Demand Order Statistic = 6	(.0310, .3123)	(.0555, .3470)
Percentile Method Percentile = 75	(.0047, .2990)	(.1550, .3220)
Ordinal Leadtime Method Demand Order Statistic = 1	(-.0164, .1011)	(-.0484, .1224)
Summed Ordinal Leadtime Method Demand Order Statistic = 1	(-.0055, .1267)	(-.0480, .1558)
Pseudo Leadtime Demand Method Demand Order Statistic = 1	(-.0063, .2460)	(-.0079, .2006)
Percentile Method Percentile = 15	(-.0201, .0099)	(-.3010, .1472)

When the demand order statistic equaled 6 or the percentile equaled 75, for 7 of 8 cases with 90 percent confidence, we can conclude that the trend purchase criteria is superior to the current purchase criteria. When the demand order statistic equaled 1 or the percentile equaled 15, there is not sufficient evidence to conclude that the trend purchase criteria is superior to the current purchase criteria for any of the eight cases. However, we will conclude that for these cases, the trend purchase criteria is as good as the current purchase criteria. Therefore, based on the analysis of the paired-t confidence intervals shown in TABLE XVI, we conclude that the trend purchase criteria is preferred to the current purchase criteria. This result is consistent with the conclusion of the analysis of the purchase criteria for "low" demand items.

2. Nonparametric Methods for Calculating Reorder Level - Four nonparametric methods were tested for setting the reorder level for "medium" demand items as discussed in the approach. Q was calculated using the EOQ (Avg 4 Qtr) order quantity and the trend purchase criteria was used as the purchase criteria for all items. TABLE XVII displays the average and 90 percent confidence intervals for the SMA/($OH+$DI) statistics using the four replications for the 1H and 1R Cog items as the demand order statistic or the percentile were varied among the four methods. To test whether one of the nonparametric methods for setting the reorder level for "medium" demand items was more cost effective than the others, the best setting for the demand order statistic or the percentile was chosen for each method. That is, that setting of the order statistic or percentile which produced the largest average SMA/($OH+$DI) statistic was defined as the best setting. TABLE XVIII displays the best order statistic or percentile for each method, the value of the SMA/($OH+$DI) statistic for each replication and the resulting average SMA/($OH+$DI). It is hypothesized that within cog the average SMA/($OH+$DI) statistics are equal for each method. A one factor ANOVA was performed for each Cog to test these hypotheses with the results displayed in TABLE XIX. The critical value of F for .05 significance with 3 and 12 degrees of freedom is 3.49 which is larger than the F-test statistics of 0.003 for 1H items and 0.206 for 1R items. Therefore, there is not sufficient evidence to reject the hypothesis for either Cog.

Since there is not sufficient evidence to choose one of the methods based on how effectively the method spends money, the OL Method is the preferred nonparametric method because of simplicity of understanding and implementation. This result is consistent with the conclusion of the analysis of the nonparametric methods for calculating the reorder level for "low" demand items.

TABLE XVII

Average and 90% Confidence Intervals for the SMA/($OH+$DI) Statistics

	1H	1R
Ordinal Leadtime Method,		
Demand Order Statistic = 7	.8659 ± .6608	1.3941 ± .2816
= 6	.9204 ± .7230	1.4723 ± .2434
= 5	.9357 ± .7436	1.5316 ± .2956
= 4	.9402 ± .7600	1.5394 ± .2698
= 3	.9053 ± .7327	1.5923 ± .3357
= 2	.8742 ± .7135	1.6781 ± .3373
= 1	.8598 ± .7218	1.6618 ± .4074
Summed Ordinal Leadtime Method,		
Demand Order Statistic = 7	.9710 ± .7595	1.4259 ± .3363
= 6	.9790 ± .7778	1.5910 ± .3232
= 5	.9484 ± .7628	1.6235 ± .3319
= 4	.9263 ± .7503	1.5923 ± .3862
= 3	.9174 ± .7529	1.5796 ± .3684
= 2	.8802 ± .7211	1.5985 ± .3076
= 1	.8721 ± .7274	1.6617 ± .4072
Pseudo Leadtime Demand Method,		
Demand Order Statistic = 7	.9401 ± .7212	1.4794 ± .2620
= 6	.9442 ± .7254	1.4622 ± .2577
= 5	.9502 ± .7331	1.4678 ± .3674
= 4	.9554 ± .7480	1.4667 ± .3171
= 3	.9658 ± .7644	1.4890 ± .3136
= 2	.9681 ± .7766	1.5344 ± .2863
= 1	.9654 ± .7762	1.5116 ± .2296
Percentile Method,		
Percentile = 85	.7897 ± .5933	1.2028 ± .2216
= 75	.8762 ± .6635	1.2856 ± .1916
= 65	.9368 ± .7288	1.4852 ± .2356
= 50	.9443 ± .7513	1.5335 ± .3004
= 35	.9305 ± .7491	1.5895 ± .3408
= 25	.9022 ± .7375	1.5874 ± .3377
= 15	.8693 ± .7112	1.5441 ± .4920

TABLE XVIII
The "Best" Demand Order Statistic or Percentile for Each Nonparametric Method

1H

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 4	1.3716	.8619	.0575	1.4701	.9402
Summed Ordinal Leadtime Method - Dmd Order Statistic = 6	1.4136	.9291	.0636	1.51	.9790
Pseudo Leadtime Dmd Method - Dmd Order Statistic = 2	1.3627	.9073	.0623	1.5402	.9681
Percentile Method - Percentile = 50	1.3478	.894	.0621	1.4733	.9443

1R

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 2	1.6101	2.1003	1.5235	1.4785	1.6781
Summed Ordinal Leadtime Method - Dmd Order Statistic = 1	1.4513	2.1761	1.4626	1.557	1.6617
Pseudo Leadtime Dmd Method - Dmd Order Statistic = 2	1.3673	1.8937	1.4053	1.4713	1.5344
Percentile Method - Percentile = 35	1.3836	2.0189	1.4857	1.4701	1.5895

NOTE: Quarters of Demand Data = 8

TABLE XIX
ANOVA Table

1H

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-Ratio
Between Methods	.0041	3	.0013	0.003
Residual	5.0941	12	.4245	
Total	5.0983	15		

1R

Between Methods	.0532	3	.0177	0.206
Residual	1.0355	12	.0862	
Total	1.0888	15		

C. CURRENT PROCEDURES VS. OL METHOD. Since for "low" and "medium" demand items the OL Method is the preferred nonparametric method for computing the reorder level and the trend purchase criteria is the preferred purchase criteria they were compared with the current procedures for controlling the inventory of the "low" and "medium" demand items. In the discussions below for "low" demand items, the phrase "Ordinal Leadtime Method" will mean that the OL Method with the demand order statistic equal to its best setting was used for computing the reorder level, Q was set equal to one and purchases were made using the trend purchase criteria. In the discussions below for "medium" demand items the phrase "Ordinal Leadtime Method" will mean the same as the OL Method for "low" demand items except that Q was computed using the EOQ (Avg 4 Qtr) order quantity.

1. "Low" Demand Items. SPCC and ASO currently set the reorder level equal to zero for "low" demand items. SPCC suppresses buys for "low" demand items until the item is in a backorder position and then only buys the deficiency

(exceptions to this buying policy are funded planned program requirements (PPRs) and Numerical Stockage Objectives (NSOs)). ASO also suppresses buys for "low" demand items until the item is in a backorder position but ASO buys the deficiency plus one. Inventory management for the four samples of 1H items and the four samples of 1R items was simulated using these current methods. TABLE XX displays the value of the SMA/($OH+$DI) statistic for each 1H and 1R replication when the Ordinal Leadtime Method and the current procedures were used to control the inventory of the "low" demand items. TABLE XX also displays the difference between the SMA/($OH+$DI) statistics when using the Ordinal Leadtime Method and the current procedures. These differences were used to construct paired-t 90 percent confidence intervals. The paired-t confidence interval tests the hypothesis that there is a difference in the SMA/($OH+$DI) statistic between the two methods being compared with 90 percent confidence. If the confidence interval does not contain zero then we can conclude that one method is superior to the other method in terms of SMA/($OH+$DI) For both 1H and 1R Cog items with 90 percent confidence we can conclude that the Ordinal Leadtime Method is superior to current procedures for controlling the inventory of "low" demand items. Therefore, based on the analysis of the paired-t confidence intervals shown in TABLE XX, we conclude that the Ordinal Leadtime Method is preferred to the current procedures for controlling the inventory of "low" demand items.

TABLE XX
Current Procedure vs. Ordinal Leadtime Method for "Low" Demand Items

1H

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 2	4.5274	3.9738	4.1748	3.0217	3.9244
Current Procedures	2.6967	2.3373	2.8644	1.652	2.3876
Difference	1.8307	1.6365	1.3104	1.3697	1.5368

Paired-t 90% Confidence Interval = (1.2522, 1.8213)

1R

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 5	5.0173	3.5433	4.9957	4.9971	4.6383
Current Procedures	4.2195	2.7478	5.0885	4.065	4.0302
Difference	.7978	.7955	-0.0928	.9321	.6081

Paired-t 90% Confidence Interval = (.0532, 1.1630)

NOTE: Quarters of Demand Data = 8

Inventory management for the four samples of 1H items and the four samples of 1R items was also simulated using the 5A simulation model described in the Technical Approach without modifications; i.e., using the wholesale simulation model which employs the current UICP rules to calculate reorder level and order quantity. Under the current UICP procedures, the leadtime demand was assumed to be described by the Poisson Distribution, the Maximum Allowable Risk (DEN V102) was set to .99 and the Essentiality-Weighted Shortage Cost (λE) was set to \$.015 and \$270 for 1H and 1R, respectively.

TABLE XXI displays the value of the SMA/(\$OH+\$DI) statistic for each 1H and 1R replication when the OL Method and the UICP procedures were used to control the inventory of the "low" demand items. TABLE XXI also displays the differences between the SMA/(\$OH+\$DI) statistics for the two processes. These differences were used to construct paired-t 90 percent confidence intervals. Based on these confidence intervals, we cannot conclude that either the OL Method or the UICP procedures is superior for 1H items, while for 1R items we can conclude that the OL Method is superior to the UICP procedures for controlling the inventory of "low" demand items.

TABLE XXI
UICP Procedures vs. Ordinal Leadtime Method for "Low" Demand Items

IH

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 2	4.5274	3.9738	4.1748	3.0217	3.9244
UICP Procedures	4.925	.2823	3.8515	3.3737	3.1081
Difference	-0.3976	3.6915	.3233	-0.352	.8163

Paired-t 90% Confidence Interval = (-1.4719, 3.1045)

1R

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 5	5.0173	3.5433	4.9957	4.9971	4.6383
UICP Procedures	2.3734	1.711	2.3945	2.4582	2.2342
Difference	2.6439	1.8323	2.6012	2.5389	2.4040

Paired-t 90% Confidence Interval = (1.9527, 2.8553)

NOTE: Quarters of Demand Data = 8

2. "Medium" Demand Items. SPCC and ASO currently use the UICP procedures to determine the reorder level and order quantity for "medium" demand items. Inventory management for the four samples of 1H items and the four samples of 1R items was therefore simulated using the 5A simulation model described in the Technical Approach without modifications. Under current UICP procedures, the leadtime demand was assumed to be described by the Normal Distribution, the Maximum Allowable Risk (DEN V102) was set to .35 and .40 and the Essentiality-Weighted Shortage Cost (λE) was set to $175 and $90 for 1H and 1R, respectively.

TABLE XXII displays the value of the SMA/($OH+$DI) statistic for each 1H and 1R replication when the OL Method and the UICP procedures were used to control the inventory of the "medium" demand items. TABLE XXII also displays the differences between the SMA/($OH+$DI) statistics for those two processes. These differences were used to construct paired-t 90 percent confidence intervals. Based on these confidence intervals, we cannot conclude that either the OL Method or the UICP procedures is superior for 1H items, while for 1R items we can conclude that the OL Method is superior to the UICP procedures. Therefore, based on the analysis of the paired-t confidence intervals shown in TABLE XXII we conclude that the OL Method is preferred to the current procedures for controlling the inventory of "medium" demand items.

TABLE XXII
UICP Procedures vs. Ordinal Leadtime Method for "Medium" Demand Items

1H

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 4	1.3716	.8619	.0575	1.4701	.9402
UICP Procedures	1.3134	.9819	.0616	1.3095	.9165
Difference	.0582	-0.12	-0.0041	.1606	.0237

Paired-t 90% Confidence Interval (-0.1144, .1618)

1R

	Replication 1	Replication 2	Replication 3	Replication 4	Average
Ordinal Leadtime Method - Dmd Order Statistic = 2	1.6101	2.1003	1.5235	1.4785	1.6781
UICP Procedures	1.0477	1.2552	1.0716	1.0033	1.0945
Difference	.5624	.8451	.4519	.4752	.5836

Paired-t 90% Confidence Interval = (.3700, .7952)

NOTE: Quarters of Demand Data = 8

IV. SUMMARY AND CONCLUSIONS

In this report four nonparametric methods were tested for calculating the reorder level for "low" and "medium" demand items. Performance in this study was measured in terms of an economic statistic resulting from dividing SMA by the dollar value of the on-hand inventory and the due-in material. The four nonparametric methods for setting reorder level were tested with Q set equal to one for "low" demand items while for "medium" demand items the EOQ (Avg 4 Qtr) method was used to calculate Q. None of the four nonparametric methods for setting the reorder level were superior to the others for either the "low" or the "medium" demand items. The OL Method was therefore preferred to the others based on simplicity of understanding and implementation.

In addition, a trend purchase criteria was compared to the current purchase criteria for both "low" and "medium" demand items. The trend purchase criteria was found to be superior to the current purchase criteria for both "low" and "medium" demand items. For "low" demand items, four methods for calculating Q were tested to see if they improved performance compared to setting Q equal to one. None of the four methods for calculating Q improved performance. Economic considerations were added to the four nonparametric methods and were evaluated using "low" demand items. Including economic considerations did not improve performance.

The Ordinal Leadtime Method for calculating the reorder level with Q set equal to one and purchases made using the trend purchase criteria were compared to the current procedures for controlling the inventory of "low" demand items. The Ordinal Leadtime Method for calculating the reorder level with Q set equal to one and purchases made using the trend purchase criteria were preferred in terms of the SMA/($OH+$DI) statistic to the current procedures. The OL Method

for calculating the reorder level with Q calculated using EOQ (Avg 4 Qtr) and purchases made using the trend purchase criteria were compared with the current procedures for controlling the inventory of "medium" demand items. This method was preferred in terms of the SMA/($OH+$DI) statistic to the current procedures.

TABLE XXIII contains the average $OH+$DI and SMA statistics when the current procedures and the OL Method for calculating the reorder level with Q set equal to one and purchases made using the trend purchase criteria were used to control the inventory of "low" demand 1H and 1R Cog items. TABLE XXIII also contains these statistics for "medium" demand 1H and 1R Cog items except with Q calculated using EOQ (Avg 4 Qtr).

TABLE XXIII
Current Procedures vs. Recommended Procedures

		"Low" Demand Items		"Medium" Demand Items	
Cog	Procedures	$OH+$DI	SMA	$OH+$DI	SMA
1H	Current	603,812.52	12.7	7,115,062.09	83.9
	OL Method	960,289.37	36.9	4,292,756.72	49.9
1R	Current	815,614.86	31.4	7,175,738.28	78.0
	Leadtime Method	1,031,683.30	47.0	2,582,175.05	42.6

The Chief of Naval Operations (CNO) target goal for SMA as specified in reference (8) of Appendix A is 85%. The 85% SMA goal is unattainable for "medium" demand items when the recommended procedures for controlling the inventory are used. Therefore, while the OL Method for calculating the reorder level with Q calculated using EOQ (Avg 4 Qtr) and purchases made using the trend purchase criteria are preferred in terms of the SMA/($OH+$DI) statistic to the current procedures for controlling the inventory of "medium" demand items, the SMA statistic that results when these policies are followed is not acceptable.

V. RECOMMENDATIONS

FMSO recommends that for "low" demand items the reorder level be calculated using the Ordinal Leadtime Method with Q set equal to one and purchases be made using the trend purchase criteria. For "medium" demand items, FMSO recommends that the current procedures for controlling the inventory of "medium" demand items be retained.

APPENDIX A: REFERENCES

1. Supply System Design Specifications (SSDS) Application/Operation (A/O) D01 (Leadtime Computation, Demand Forecasting, Activity Stocking Criteria and Levels Computation) of 1 Jan 1983.

2. Naval Postgraduate School (NPS) Thesis, An Analysis of the Navy Ships Parts Control Center Inventory Model and a Possible Alternative, Jun 1977.

3. COMNAVSUPSYSCOM ltr 04A7/JHM of 15 Oct 1981.

4. FMSO ltr 9322-D86/JAM/283 5250 of 1 Nov 1982.

5. Operations Analysis Study Report 128.

6. Ships Supply Support Study by James W. Prichard of 15 Jun 1973.

7. Averill M. Law and W. David Kelton, Simulation Modeling and Analysis, McGraw-Hill, Inc. 1982.

8. NAVSUPINST 5220.15A.

APPENDIX B: PAIRED-t CONFIDENCE INTERVAL CONSTRUCTION

The table below displays the SMA/($OH+$DI) statistics for each 1H Cog replication for both the current purchase criteria and the trend purchase criteria when the Ordinal Leadtime Method for calculating the reorder level is used with the demand order statistic and the quarters of demand set equal to 6 and 8, respectively. The table also displays the difference between the SMA/($OH+$DI) statistics for the two purchase criterias for each replication This data is taken from TABLE II.

1H - Ordinal Leadtime Method - Demand Order Statistic = 6 - Quarters of Demand Data = 8

	Replication 1	Replication 2	Replication 3	Replication 4
Trend Purchase Criteria	4.2465	3.855	3.1281	2.8187
Current Purchase Criteria	3.4128	.5763	2.3419	2.2832
Difference	.8337	3.2787	.7862	.5355

Define Z_j to be equal to the difference for the j^{th} replication, then let

$$\bar{Z}(n) = \frac{\sum_{j=1}^{n} Z_j}{n} = \frac{\sum_{j=1}^{4} Z_j}{4} = \bar{Z}(4) = 1.3585$$

$$\hat{\sigma}^2\left[Z(n)\right] = \frac{\sum_{j=1}^{n}\left[Z_j - \bar{Z}(n)\right]^2}{n(n-1)} = \frac{\sum_{j=1}^{4}\left[Z_j - \bar{Z}(n)\right]^2}{(4)(3)} = .4139$$

and form the $100(1-\alpha)$ percent confidence interval

$$\overline{Z}(n) \pm (t_{n-1}, 1 - \frac{\alpha}{2}) \left(\sqrt{\sigma^2 \left[Z(n) \right]} \right.$$

Letting $\alpha = .1$ results in a 90 percent confidence interval,

$1.3585 \pm (2.353) \left(\sqrt{.4139} \right) = 1.3585 \pm 1.5139$ or $(-.1553, 2.8724)$

APPENDIX C: OUTPUT STATISTICS FOR "LOW" DEMAND ITEMS

This appendix contains the SMA/($OH+$DI), SMA, $OH+$DI, ADD and #PI statistics for the four 1H and the four 1R "low" demand replications as the demand order statistic or the percentile were varied for the four nonparametric methods of calculating the reorder level. Q was set equal to one and purchases were made using the trend purchase criteria.

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TABLE I
SMA/($OH+$DI)

	1H				1R			
	Replication 1	Replication 2	Replication 3	Replication 4	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method								
Demand Order Statistic = 7	3.7805	.5434	2.7807	2.6528	4.7921	2.7130	4.5727	4.6307
= 6	4.2465	3.855	3.1281	2.8187	4.6021	2.6734	4.9489	4.7941
= 5	4.4385	4.1128	3.9547	2.9701	5.0173	3.5433	4.9957	4.9971
= 4	4.66	4.035	3.9599	2.9944	5.1628	2.5399	5.2558	5.2102
= 3	4.5579	3.9718	4.0713	2.9595	4.9948	2.5761	5.2747	4.918
= 2	4.5274	3.9738	4.1748	3.0217	5.1654	2.611	5.281	4.6795
= 1	4.55	3.9196	4.1269	2.9999	5.0547	2.6029	5.411	4.7182
Summed Ordinal Leadtime Method								
Demand Order Statistic = 7	4.2785	1.1439	3.2813	3.0166	4.9778	2.6354	4.4746	4.6454
= 6	4.6491	4.1599	3.8801	3.0914	4.8522	2.9541	4.9821	4.7069
= 5	4.7708	4.2525	4.0963	3.0516	4.8422	3.5655	5.08	4.9676
= 4	4.7226	4.1079	4.0265	3.0898	4.8765	2.5639	5.2377	4 8444
= 3	4.5721	3.9606	4.0973	2.9993	4.8322	2.6329	5.1347	4.8258
= 2	4.623	3.9456	4.1867	2.9992	4.9913	2.6102	5.1967	4.9447
= 1	4.52	3.9437	4.1621	2.9844	5.1654	2.6029	5.1516	4.8634
Pseudo Leadtime Demand Method								
Demand Order Statistic = 7	3.6679	1.2126	2.9542	2.5247	4.0155	2.6262	3.7718	4.0136
= 6	3.7623	1.1872	3.0019	2.5424	3.8729	2.7549	3.9108	3.6767
= 5	3.9306	1.1591	3.0606	2.5768	3.9519	2.6345	3.8898	3.8178
= 4	4.0243	1.133	3.1089	2.9023	4.2518	2.6273	3.9689	4.1292
= 3	4.1031	1.1031	3.1721	2.9437	4.2919	2.5719	4.0247	4.1132
= 2	4.2279	1.0815	3.2601	2.9517	4.2381	2.608	4.2846	4.4105
= 1	4.36	1.0552	3.256	2.9632	4.6378	3.3114	4.2592	4.2917
Percentile Method								
Percentile = 85	2.5952	.5844	2.2806	1.9148	3.1732	2.0266	2.7457	3.0251
= 75	3.44	.6061	2.7602	2.4823	3.7976	2.1144	3.2518	3.4241
= 65	3.9963	.8479	2.9847	2.8543	4.08	2.9125	3.8622	4.4917
= 50	4.5891	4.1262	3.9402	3.0005	4.608	2.9617	5.0597	4.8287
= 35	4.702	4.1469	4.0438	3.0585	4.8727	3.1105	5.1465	4.8218
= 25	4.6087	3.9967	4.1124	3.0956	4.9135	2.6374	5.15	4.8305
= 15	4.66	3.9883	4.2407	3.0556	5.0621	2.6032	5.3319	4.9872

NOTE: Quarters of Demand Data = 8

TABLE II
SMA

	1H				1R			
	Replication 1	Replication 2	Replication 3	Replication 4	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method								
Demand Order Statistic = 7	.496	.488	.452	.465	.503	.451	.479	.472
= 6	.446	.442	.431	.434	.479	.458	.489	.471
= 5	.413	.406	.398	.396	.483	.446	.487	.465
= 4	.394	.384	.386	.379	.469	.444	.493	.461
= 3	.381	.368	.383	.366	.457	.445	.487	.451
= 2	.373	.366	.375	.362	.466	.440	.487	.452
= 1	.374	.361	.372	.360	.450	.439	.472	.455
Summed Ordinal Leadtime Method								
Demand Order Statistic = 7	.518	.501	.488	.478	.510	.463	.512	.488
= 6	.449	.441	.439	.432	.490	.469	.490	.472
= 5	.408	.401	.403	.393	.476	.447	.479	.458
= 4	.394	.384	.386	.378	.463	.453	.484	.454
= 3	.376	.366	.379	.367	.461	.442	.473	.443
= 2	.373	.365	.373	.364	.455	.440	.475	.451
= 1	.372	.363	.372	.361	.466	.439	.473	.444
Pseudo Leadtime Demand Method								
Demand Order Statistic = 7	.577	.574	.555	.536	.537	.511	.535	.524
= 6	.569	.561	.548	.538	.529	.503	.548	.508
= 5	.547	.535	.528	.513	.509	.491	.529	.501
= 4	.521	.510	.504	.494	.524	.483	.514	.502
= 3	.494	.486	.479	.473	.504	.474	.500	.476
= 2	.472	.467	.459	.449	.471	.465	.494	.482
= 1	.457	.450	.445	.438	.496	.459	.489	.474
Percentile Method								
Percentile = 85	.586	.578	.556	.563	.580	.537	.553	.538
= 75	.569	.561	.546	.550	.545	.520	.535	.535
= 65	.505	.492	.478	.482	.501	.483	.499	.493
= 50	.437	.423	.418	.416	.469	.462	.488	.455
= 35	.402	.387	.394	.381	.467	.451	.476	.455
= 25	.380	.370	.381	.372	.444	.443	.471	.447
= 15	.376	.363	.371	.363	.469	.439	.483	.452

NOTE: Quarters of Demand Data = 8

TABLE III
$OH+$DI

	1H				1R			
	Replication 1	Replication 2	Replication 3	Replication 4	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method								
Demand Order Statistic = 7	1,312,011.52	8,980,080.36	1,625,456.00	1,752,997.52	1,174,325.13	1,662,332.42	1,047,509.02	1,019,277.31
= 6	1,050,278.43	1,146,550.95	1,377,812.10	1,539,735.96	1,040,831.90	1,713,167.07	988,088.41	982,459.97
= 5	930,492.00	987,158.15	1,006,390.80	1,333,289.14	962,666.58	1,258,696.14	974,838.33	930,532.15
= 4	846,195.16	951,666.95	974,778.03	1,265,698.23	908,421.26	1,748,111.73	938,010.69	884,794.53
= 3	835,908.87	926,534.65	940,724.94	1,236,692.53	914,944.99	1,727,392.19	923,270.58	917,037.69
= 2	823,863.61	921,023.01	898,253.51	1,198,017.34	902,148.22	1,685,175.89	922,174.02	965,912.73
= 1	822,295.99	921,017.09	901,393.52	1,200,031.47	890,255.69	1,686,598.56	872,304.82	964,357.06
Summed Ordinal Leadtime Method								
Demand Order Statistic = 7	1,210,711.84	4,379,550.73	1,487,188.06	1,584,533.95	1,161,350.67	1,756,818.65	1,144,213.09	1,050,480.77
= 6	965,776.49	1,060,126.81	1,131,415.73	1,397,429.22	1,009,861.33	1,587,608.95	983,516.03	1,002,785.39
= 5	855,198.22	942,967.55	983,820.99	1,287,862.20	983,015.05	1,253,688.93	942,916.45	921,971.72
= 4	834,294.92	934,774.47	958,637.68	1,223,380.45	949,443.05	1,766,836.25	924,062.03	937,166.14
= 3	822,371.80	924,093.41	925,001.04	1,223,629.44	954,025.20	1,678,763.96	921,186.33	917,987.76
= 2	806,834.38	925,079.27	890,918.52	1,213,641.75	911,579.52	1,685,708.89	914,044.99	912,093.61
= 1	823,514.69	920,457.43	893,786.38	1,209,610.25	902,148.22	1,686,598.56	918,155.63	912,933.25
Pseudo Leadtime Demand Method								
Demand Order Statistic = 7	1,573,094.30	4,733,296.09	1,878,676.93	2,122,991.02	1,425,473.05	1,945,752.47	1,418,398.38	1,305,534.06
= 6	1,512,366.55	4,725,443.85	1,825,536.62	2,116,126.66	1,365,886.48	1,825,829.31	1,401,254.69	1,381,667.30
= 5	1,391,661.08	4,615,769.77	1,725,144.53	1,990,854.85	1,287,989.24	1,863,716.74	1,359,983.46	1,312,267.70
= 4	1,294,628.91	4,501,468.26	1,621,132.83	1,702,112.42	1,232,425.11	1,838,381.02	1,295,074.00	1,215,722.65
= 3	1,203,967.06	4,405,793.38	1,510,041.24	1,606,800.37	1,174,299.00	1,843,014.42	1,242,334.92	1,157,240.85
= 2	1,116,406.06	4,317,983.45	1,407,917.18	1,521,135.54	1,111,353.15	1,782,965.90	1,152,969.23	1,092,836.44
= 1	1,047,991.63	4,264,598.61	1,366,720.65	1,478,134.64	1,069,477.71	1,386,112.81	1,148,095.16	1,104,446.07
Percentile Method								
Percentile = 85	2,258,001.81	9,889,163.75	2,437,904.60	2,940,261.92	1,931,885.37	2,649,697.93	2,014,023.56	1,778,433.72
= 75	1,654,081.61	9,256,227.43	1,987,142.80	2,215,694.03	1,435,114.38	2,459,280.09	1,645,257.23	1,562,458.51
= 65	1,263,676.52	5,802,258.66	1,601,482.32	1,688,656.00	1,227,931.98	1,658,368.97	1,292,024.28	1,097,571.14
= 50	952,263.62	1,025,146.91	1,060,847.70	1,386,448.06	1,017,794.40	1,559,921.40	964,491.22	942,276.28
= 35	854,958.22	933,225.83	974,323.27	1,245,695.35	958,398.61	1,449,911.37	924,908.95	943,621.96
= 25	824,525.80	925,761.07	926,473.12	1,201,695.13	903,632.37	1,679,656.21	914,570.82	925,367.86
= 15	806,943.52	910,155.97	874,864.21	1,187,990.93	926,500.44	1,686,411.89	905,872.09	906,327.36

NOTE: Quarters of Demand Data = 8

TABLE IV
ADD

	1H				1R			
	Replication 1	Replication 2	Replication 3	Replication 4	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method								
Demand Order Statistic = 7	144.79	161.54	175.33	164.82	113.96	138.22	128.[illegible]	132.02
= 6	149.70	153.23	157.76	158.45	116.89	137.76	115.[illegible]	120.32
= 5	159.17	163.13	164.09	165.61	117.45	140.19	121.[illegible]	125.98
= 4	164.42	168.88	168.45	171.23	121.27	145.04	119.[illegible]	126.96
= 3	167.78	173.61	170.43	176.63	117.11	143.20	119.[illegible]	126.86
= 2	172.15	175.01	172.94	178.96	118.85	137.33	123.[illegible]	126.72
= 1	171.24	175.99	172.88	179.41	117.14	137.43	127.[illegible]	126.81
Summed Ordinal Leadtime Method								
Demand Order Statistic = 7	126.12	135.18	137.54	138.43	106.10	137.44	120.[illegible]	117.21
= 6	144.20	147.40	149.38	151.47	112.24	144.12	111.[illegible]	119.15
= 5	157.22	161.48	162.55	163.41	117.05	129.29	120.[illegible]	123.82
= 4	162.41	167.52	167.78	171.22	119.12	134.54	117.[illegible]	127.44
= 3	168.86	173.68	171.93	174.97	120.67	138.04	124.[illegible]	128.02
= 2	171.18	175.73	172.73	177.71	117.20	137.08	127.[illegible]	127.25
= 1	171.48	175.59	172.55	178.81	118.85	137.43	126.[illegible]	130.29
Pseudo Leadtime Demand Method								
Demand Order Statistic = 7	116.35	124.91	130.17	137.06	102.34	120.76	109.[illegible]	106.02
= 6	116.40	119.59	124.44	125.15	104.53	120.03	105.[illegible]	106.30
= 5	118.48	122.65	125.32	127.85	107.47	126.08	110.[illegible]	115.96
= 4	123.27	127.15	130.45	131.33	104.30	128.66	109.[illegible]	113.75
= 3	130.14	134.10	138.11	137.97	113.14	135.02	111.[illegible]	120.05
= 2	136.59	139.28	143.45	143.38	116.57	129.83	112.[illegible]	114.83
= 1	140.00	143.80	147.66	147.07	109.27	138.93	115.[illegible]	118.85
Percentile Method								
Percentile = 85	140.02	165.74	177.40	154.48	99.24	127.30	123.[illegible]	114.97
= 75	120.61	125.91	133.39	128.24	108.75	118.93	105.[illegible]	106.33
= 65	131.39	133.75	142.78	139.92	109.74	132.84	116.[illegible]	115.16
= 50	150.57	153.66	158.70	157.44	122.63	122.70	121.[illegible]	128.82
= 35	159.33	166.27	165.41	169.09	119.12	137.16	121.[illegible]	125.31
= 25	167.20	172.86	169.63	175.81	120.71	141.68	123.[illegible]	131.74
= 15	169.86	175.57	173.51	178.97	123.85	137.45	117.[illegible]	127.33

NOTE: Quarters of Demand Data = 8

TABLE V
#P1

	1H				1R			
	Replication 1	Replication 2	Replication 3	Replication 4	Replication 1	Replication 2	Replication 3	Replication 4
Ordinal Leadtime Method								
Demand Order Statistic = 7	440.6	437.8	453.0	446.0	454.7	497.7	456.0	495.0
= 6	470.6	475.8	467.2	470.8	474.0	494.0	450.0	495.7
= 5	498.8	500.6	494.6	501.0	479.0	500.3	454.0	507.7
= 4	512.0	513.4	508.0	515.8	477.0	506.3	456.3	514.0
= 3	520.6	525.2	516.2	526.4	482.0	509.7	459.3	516.0
= 2	526.6	528.0	521.0	532.0	479.0	511.7	460.3	516.7
= 1	527.2	528.6	521.6	534.0	481.7	513.3	469.0	517.7
Summed Ordinal Leadtime Method								
Demand Order Statistic = 7	545.4	550.6	555.6	559.4	548.0	601.0	534.0	588.0
= 6	528.6	529.0	527.0	537.8	510.7	544.0	488.0	542.3
= 5	526.4	525.6	520.6	536.0	491.7	523.0	464.7	526.7
= 4	519.8	520.6	515.8	530.8	483.3	516.7	463.0	517.0
= 3	524.0	527.4	517.6	532.2	479.3	512.7	461.3	519.3
= 2	527.0	528.0	521.0	532.8	482.0	512.7	462.0	517.7
= 1	527.2	528.4	521.6	533.4	479.0	513.3	463.3	517.7
Pseudo Leadtime Demand Method								
Demand Order Statistic = 7	556.6	553.6	558.2	575.6	625.0	681.3	599.3	656.7
= 6	556.8	558.4	560.0	567.4	612.0	651.0	586.3	641.0
= 5	548.8	551.2	553.0	557.0	587.7	624.3	546.7	614.0
= 4	533.8	536.4	536.2	541	548.7	590.0	520.3	579.3
= 3	522.6	520.8	519.2	530.8	517.0	561.7	496.7	554.7
= 2	513.8	511.6	510.0	521.6	498.0	535.7	478.7	537.0
= 1	497.8	492.6	495.4	502.4	480.3	518.3	462.0	518.3
Percentile Method								
Percentile = 85	459.0	453.0	470.0	464.4	559.7	593.7	555.3	599.0
= 75	458.4	457.8	465.6	458.0	496.7	527.0	481.7	524.7
= 65	453.2	454.2	450.4	457.4	470.3	496.3	451.7	491.0
= 50	497.6	498.8	498.2	508.8	486.3	516.0	462.3	523.3
= 35	511.2	516.6	509.8	522.0	482.3	514.7	460.3	516.3
= 25	523.6	524.6	516.6	529.6	482.3	513.0	462.0	518.7
= 15	527.4	529.0	523.2	532.2	479.3	513.0	462.7	518.7

NOTE: Quarters of Demand Data = 8

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13. ABSTRACT

This study evaluates four distribution free or nonparametric methods for setting levels for "low" and "medium" demand items. The study also analyzes additional techniques for setting the order quantity and the inclusion of economic considerations in setting levels. Performance in the study was measured in terms of an economic statistic resulting from dividing Supply Material Availability (SMA) by the dollar value of the on-hand inventory and the due-in material.

The performance indicates that for "low" demand items, the reorder level should be calculated using the Ordinal Leadtime Method with the order quantity (Q) set equal to one and that purchases be made using the trend purchase criteria. For "medium" demand items, the Ordinal Leadtime Method for calculating the reorder level with Q calculated using the Wilson Economic Order Quantity formula and purchases made using the Trend Purchase Criteria shows an improvement in terms of the performance statistic over the current procedures. However, the SMA that results when these policies are followed is unacceptable; therefore, it is recommended that current procedures for controlling the inventory of "medium" demand items be retained.

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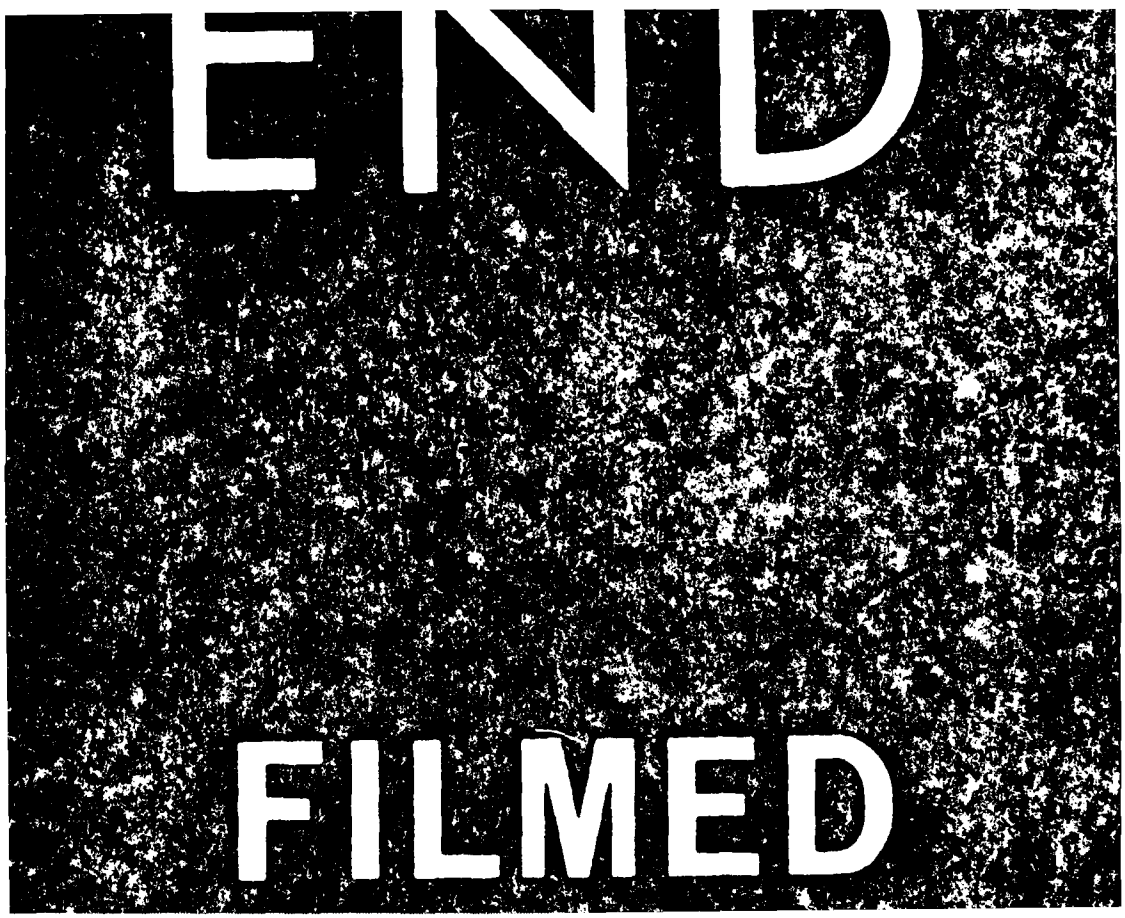
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